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AN OPTIMAL DESIGN OF CONNECTIVITY OF THE ELECTRIC CURRENT TO A STAND-ALONE COMPLEX BY USING THE SOLAR CELLS

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ABSTRACT

In recent days, the increasing demand for electrical energy has led to a significant need for power for the renewable energy. Producing the electric current from the Solar Energy (SE) is one of the best sources of renewable energies. The most significant problem facing designers of (SE) systems for individual buildings is the problem of lack of flat roof areas of these buildings, especially in the stand-alone systems where the solar panels take a considerable amount of space. Therefore, most scientific research in the field depends on "How to reduce the solar panel area with a high efficiency and power production." It is also possible that the available area gives a large surplus of useless energy.

The problem of the vast horizontal areas of solar panels can be solved in the stand-alone systems, where each solar system installed on every building feeds that same building and feeds its surplus energy in main busbar around the complex. The main busbar around the complex provides each building with the required energy and uses the surplus energy from all buildings to provide another load.

This paper introduces a complete design system of integrating photovoltaic/battery storage to a stand-alone complex isolated about the utility grid system "Off Grid system" with variety and different loads by using distributed solar cells to reach the highest efficiency and economical operation of the distribution system.

KEYWORDS: Solar Energy, solar cells, Centralized Power System Arrangement, Advanced Solar Photovoltaic, Power Logic Control Inverter & Off Grid System

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Original Article

INTRODUCTION

Today the power engineering must be concerned with the energy, economy, and ecology. Thus, the modern engineers must try to develop systems that produce large quantities of energy at low costs with minimal impact on the environment. It is essential that an increasing part of future electrical energy research and development concerned with the renewable methods of generation.

Free resources such as sunshine, flowing water, wind, and biological waste, allow production of renewable energy without incurring drastic price changes. This consistency gives people greater certainty about the cost of energy, which is good for society and the economy. [1]

The most popular renewable energy is (SE), especially in EGYPT where solar technology is utilized in the form of collectors and modules which store and convert radiation from the sun into more usable forms such as heat or electricity.

(SE) is considered to be a clean source of energy, often referred to as "green," because of its low emission of carbon, no need for fossil fuels, inexhaustible solar energy, less compensation time and more. However, like any other power generation source, there are some safety, health, and environmental concerns about (SE). [2]

TYPES OF SOLAR PHOTOVOLTAIC STAND-ALONE CONNECTED POWER SYSTEMS

Distributed Arrangement (DIA)

With DIA, the solar cells array and accompanying elements are allocated independently for each consumer, and thus it may be termed as an on-site arrangement.

Centralized Power System Arrangement (CEA)

In CEA, the equipment needed for all the complex energy requirements have been centralized and erected at one site, inside the complex boundaries. The need for the following additional equipment and tasks associated with CEA is substantial:

Electrical distribution system (EDS) with it's distributes radiating from the PC unit bus bar to supply the rural area with its energy demand.

A land area for CEA deployment.

A building to accommodate the energy storage (BS), power conditioner unit (PC), the switching devices and the instrumentation subsystems.

Teams of workers over three shifts per day for the system operation and maintenance tasks.

The DIA is characterized by the individuality and the independence for each local load. These result in the elimination of the complex control and load management tasks required for CEA.

The distributed arrangement is superior to the centralized system because the minimum total life-cycle costs are less than those of CEA and satisfy all the technical constraints, as revealed in the comparison. This paper intended to have the optimum arrangement and design of an Advanced Solar Photovoltaic (ASPV) power system to electrify a rural area. [3, 4]

METHODOLOGY

Framework Connection as the Complex is Stand-Alone

The complex is split into zones.

Each unit in the zone is fed from the solar system on the roof of this unit and the surplus of energy being pumped by power logic control inverter (PLCI) into a main bus bar which be constructed within the complex.

Each unit fed from a spare cable which fed from the surplus energy up the needs of consumers and make connections between them with Automatic Transferring System Unit (ATSU) for critical cases.

Synthetic counter should be mounted to calculate the energy consumed or pumped to main bus bar.

It is possible to benefits from surplus energy in main bus bar to lighting street lamppost and any other loads by using (SE) which stored in to the main bus bar with install counter to calculate the amount of energy consumed.

It is favoured to establish an accounting centre for the entire complex to calculate the energy consumed or pumped from each unit and establish programs required to account each unit's energy

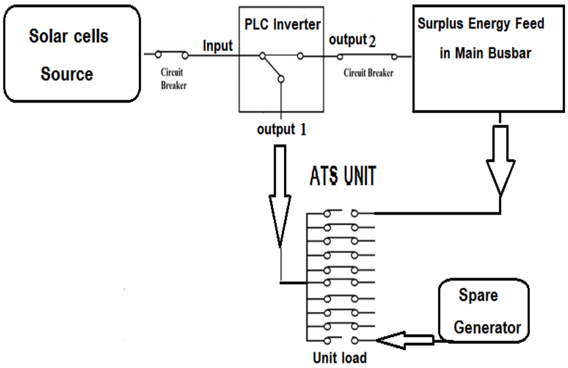

Figure 1: Single Line Diagram Connection when the Complex is Stand-Alone

Calculation Steps of Design Solar Stations Capacities

The main steps taken when designing a PV system are Load calculation, Sizing the PV system array, Charge controller sizing, Battery sizing and Inverter sizing

Load calculation and Sizing the PV system array

- **Determining the Array Load**

Designing PV system, one or more of the following parameters determines the array:

- Available aperture area,
- Available Resources (both solar and financial), and
- The load requirements

Array load = the total daily load /(Charger efficiency ×Battery efficiency ×inversion efficiency)

Array power = Array load (Watt- Hour) / Number of hours of sunshine (hour)

Module number = Array power /the power of the used module

- **Charge Controller Sizing**

The charge controller power = array current ×safety coefficient (125%).

- **Battery Sizing**

Battery capacity (amp-hours) = (Total daily load × Days of storage) / (Battery voltage × efficiency × discharge depth)

The battery capacity = (Array load×preserving days) / (Voltage× battery efficiency)

Number of conducted batteries on parallel = The batteries capacity (ampere- hour) / the battery capacity (ampere-

hour)

- **Inverter Sizing**

The inverter power = the total of loads, power (Watt) × safety factor

General Requirement for Solar System, Electrical Calculation

Some consideration must be taken in account when solar system is designed as following:

All electrical calculation and its factors are according to the rules of Egyptian code or requirements of the Ministry of Electricity and Renewable Energy.

When calculating the loads of each building, it is converted the areas to loads according to the rules of the Egyptian code where each 100 m2 equal 4 KVA for residential buildings and each 100 m2 equal 10 KVA for administration buildings.

The safe side load is equal = 1.25 × load and the demand factor of the load = 0.8 × load

The average number of operating hours is 8 hours for residential buildings and 10 hours for administration buildings, according to the requirements of the Ministry of Electricity and Renewable Energy.

The dimension of German Solar panel with 250 w equal 120 cm × 200 cm. That means each 10 m2 space of horizontal areas accommodate almost 4 German Solar panel with 250 w.

Average number of hours of sunshine equal 6 hours.

Energy in KWH for residential buildings = (Area of building × 4 KVA ÷ 100) × (1.25 safe side load) × (0.8 demand factor) × (0.8 power factor) × (8 the average number of operating hours).

Energy in KWH for administration buildings = (Area of building × 10 KVA ÷ 100) × (1.25 safe side load) × (0.8 demand factor) × (0.8 power factor) × (10 the average number of operating hours).

The average number of hours fall the sunlight on the solar panel is 6 hours.

Standard temperature condition STC: 1000 w/m^2 at 25o C.

The accounts for the component of the solar system done through the Excel program.

The accounts for the electrical lighting system of children's playgrounds, swimming pools and football playgrounds done by DIALux program.

Demonstration of the design of connectivity the electric current to a complex by using solar cells done by AutoCAD program.

CASE STUDY BASED ON OPTIMAL DESIGN

Prelude

The analytical study of the project designed in a tourist village in one of the coastal cities within the Arab Republic of Egypt and the choice came for two reasons:

First: There are large parts of the coastal cities is extended and it is difficult to access, electricity to reach them and connecting the electric current to its cost a huge amounts of money, and managerial procedures are complex. So searching for a new electrical source is a prerequisite.

Second: Under the crisis in national income of Egypt and in particular the tourism sector sources which influenced greatly influenced by the energy crisis, so it was necessary to find new solutions to stimulate this vital sector.

So the paper takes a village called Golden village locate on the Mediterranean coast near the city of Marsy Matrouh as a case study.

Figure 2: Layout Plan for the Complex

Optimal Design of Solar System to Each Building

Table 1: Calculations to Reception and Administration Building with Area 700 m2

Description	Calculations
Load calculation	Load = (700 ×10÷100) × (1.25 s.s) × (0.8 D. F) ×(0.8 P. F) × (10 hours) Load = 560 kwh
Sizing the PV system array	Array load = the total daily load / (Charger efficiency × Battery efficiency × inverter efficiency) Array load = 560 / (0.99 × 0.95 × 0.96) = 620kwh One Panel load = power of one panel × Number of hours of sunshine Where One Panel load = 250 w × 6 hours = 1,5 kwh
Sizing the actual area load	The dimension of German Solar panel with 250 w equal 120 cm × 200 cm. that is mean each 10 m2 space of horizontal areas accommodate almost 4 German Solar panel with 250 w or each 10 m2 space of horizontal areas accommodate almost 6 kwh German Solar panel The load which accommodate 700 m2 = (700 × 6) / 10 = 420 kwh
Surplus load	Surplus load for Reception and Administration Building = 420 – 620 = – 200 kwh That is mean Reception and Administration Building need 200 kwh to accommodate its load
Result 5	123
Result 6	123
Result 7	123
Result 8	123

Table 2: Calculations to Housing Complex Units Consists of 13 Units each One Consists of 1 Floors with Area 96 m2

Description	Calculations
Load calculation	Load = (96 ×13×1×4 ÷100)×(1.25 s.s)× (0.8 D. F) ×(0.8 P. F)×(8 hours) Load = 320 kwh
Sizing the PV system array	Array load = the total daily load / (Charger efficiency ×Battery efficiency ×inverter efficiency) Array load = 320 / (0.99 ×0.95 ×0.96) = 355 kwh
Sizing the actual area load	The load which accommodate 13 × 96 m2 = (1248 × 6) / 10 = 748 kwh ~ 58kwh / unit
Surplus load	Surplus load for 13 units each one consists of 1 floors with area 96 m2= 748 – 355 = + 393 kwh
Result 5	123
Result 6	123
Result 7	123
Result 8	123

Table 3: Calculations to Coffee Shops Consists of 1 Floors with Area 900 m2

Description	Calculations
Load calculation	Load = (900 ×1×10 ÷100)×(1.25 s.s) × (0.8 D. F) ×(0.8 P. F) × (8 hours) Load = 576 kwh
Sizing the PV system array	Array load = the total daily load / (Charger efficiency Battery efficiency inverter efficiency) Array load = 576 / (0.99×0.95×0.96) = 640 kwh
Sizing the actual area load	The load which accommodate 900 m2 = (900 × 6) / 10 = 540 kwh
Surplus load	Surplus load for Coffee shop consists of 1 floor with area 900 m2= 540 – 640 = – 100 kwh
Result 5	123
Result 6	123
Result 7	123
Result 8	123

Table 4: Total Surplus Load for the Complex

Description	Calculations
Total Load calculation	= (– 200 kwh urplus load from **Table 1**) + (393 kwh urplus load from **Table 2**) + (– 100 kwh urplus load from **Table 3**) = 93 kwh. That is perfect result
Sizing the PV system array	Array load = the total daily load / (Charger efficiency ×Battery efficiency ×inverter efficiency) Array load = 576 / (0.99×0.95×0.96) = 640 kwh
Sizing the actual area load	The load which accommodate 900 m2 = (900 × 6) / 10 = 540 kwh
Surplus load	Surplus load for Coffee shop consists of 1 floor with area 900 m2= 540 – 640 = – 100 kwh
Result 5	123
Result 6	123
Result 7	123
Result 8	123

EVALUATION OF THE PREVIOUS DESIGN

The PVsyst program was chosen to evaluate the previous case study. The study involved the lighting of lamp posts through a solar energy system. The PVsyst program gives us a quick check of our final research results in finding the optimal design for connecting the electric current to the complex by using solar cells.

PVsyst Program

PVsyst program is software for the study and simulation of photovoltaic systems. It was designed at the University of Geneva, Switzerland. On July 1st, 2011, the University of Geneva granted an exclusive and worldwide license for the distribution and development of the PVsyst software to PVsyst version 6.4.7. [5]

The Framework Details of the Case Study

The evaluation consists of a comparison between the previous design research and the design created by the PVsyst program for a case study in lighting lamp posts by a solar energy system; two case studies of standalone systems; and a Grid with a battery design. The results are the same, so it is possible to describe one stand-alone system for a quick check of our final research results in finding the optimal design for connecting the electric current to the complex by using solar cells.

The PVsyst program is applied through seven steps to get the result of the design.

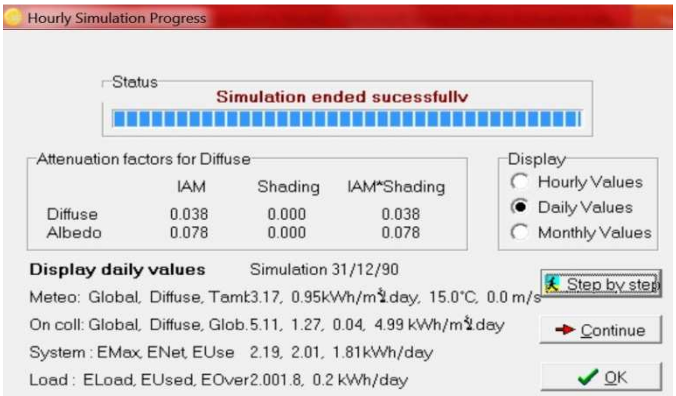

Figure 3: The Output is the Result of a Simulation to Input Data

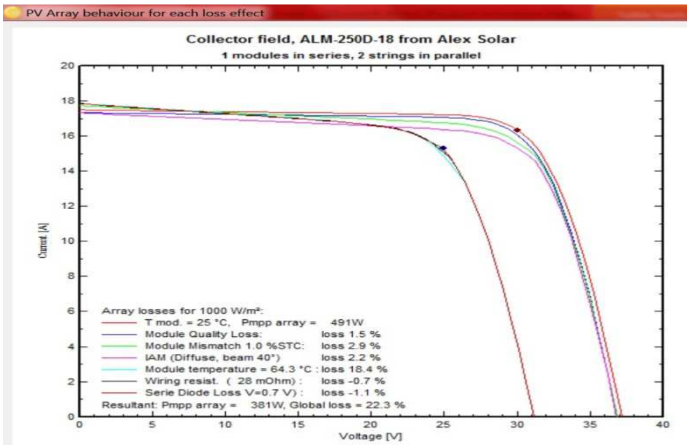

Figure 4: Characteristics of the Project

NOTES

The PVsyst program cannot make a fully designed solar system to the complex and cannot give Total Surplus Load for the complex. In this paper, PVsyst program is being used to make a quick check of part of the optimal design study.

The Manual accounts of a solar system on lamppost were designed as a no safe side load calculation according to the considerations of the Egyptian Code where the LED lamps are a constant load, and the value of start current is minimal. Also, the power factor and demand factor are taken as 1 unit and the number of operating hours taken as 10 hours per day.

The Manual accounts of a solar system on a lamppost are almost equal with the accounts of the PVsyst program, except for slight differences due to the PVsyst program's use of the system efficiency coefficient calculated to 85% instead of 90%. When calculated in the Manual, accounts of the solar system cause the efficiency coefficient to differ from one brand to another.

The PVsyst program deals with the tilt angle of the solar cells array as 30 degrees for the site within the manual calculations dealing with the tilt angle as 32 degrees for the same site, and this has a slight effect on results.

The PVsyst program calculates the number of sunlight hours, according to astronomical calculations, while manual accounts, handle the average number of operating hours as 6 hours only.

The PVsyst program identifies the timing of operating hours as "hourly distribution." Is it night or day? Manual accounts are estimated by the average number of operating hours (8 hours for residential buildings and 10 hours for administration buildings) according to the requirements of the Ministry of Electricity and Renewable Energy to economize battery capacity as much as possible.

CONCLUSIONS

The final conclusion of the paper could be listed as:

The most popular renewable energy is (SE), especially in EGYPT. Solar systems are designed to harness and convert radiation from the sun into more usable forms such as electricity or heat.

(SE) is considered to be a green source of energy and one of the cleanest resources available. (SE) benefits range from low carbon emission, no fossil fuel requirement, long-term solar resources, less payback time and more. However, like other power generation sources, (SE) has also some Safety, Health, and Environmental concerns.

The paper introduces an entirely new design system of integrating photovoltaic/battery storage to a stand-alone complex isolated in a utility grid system, or "Off Grid system," with a variety of different loads using distributed solar cells to reach the highest efficiency and economical operation of the distribution system.

A stand-alone system, where each solar system is installed on every building supplying energy to the same building and then feeding the surplus energy to the main busbar, is the solution to the problem of vast horizontal areas of solar panels. The complex and main busbar provide each building with the power it requires and the surplus energy from all construction is gathered to provide another load.

The paper introduced a comparison between Distributed (DIA) and centralized (CEA) ASPV power system arrangement. The comparison reveals that the distributed method has the superiority over the centralized one because it has

minimum total life-cycle costs less than those of CEA and satisfies all the technical constraints. The Paper intended to have the optimum arrangement and design of advanced solar photovoltaic (ASPV) power system to electrify a rural area. It enables the designer to choose the best option out of two alternatives - the distributed (DIA) and centralized (CEA).

The paper introduced optimal Calculation steps of design solar stations capacities. The main steps of design are: Load calculation, Sizing the PV system array, Charge controller sizing, Battery sizing and Inverter sizing to the complex and output the surplus energy to the entire complex.

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